

High Bandwidth Perovskite based Antenna for High-Resolution Biomedical Imaging at Terahertz

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Abstract—This paper suggests the prospective utilization of a hybrid perovskite, with a chemical name of Methylammonium Lead Iodide ($\text{CH}_3\text{NH}_3\text{PbI}_3$), in the design of a Terahertz (THz) antenna. A newly developed perovskite material has been used for the antenna design which can replace the conventional metallic patches. The proposed antenna operates in two THz bands, i.e. 3.6–7.4 THz and 8.25–10.0 THz. The realized gain of the antenna is above 4 dBi and efficiency is above 70% in overall operating bandwidth. In addition, the radiation efficiency of the designed antenna could be improved by increasing the conductivity of perovskite film with the application of an external voltage. The reported performance of the antenna design provides the proof of the concept for the possible utilization of non-metallic advanced materials such as perovskite in manufacturing antennas for THz based biomedical applications.

Keywords— Bandwidth, Perovskite; Terahertz; wireless

I. INTRODUCTION

With the increasing demands of high-speed, reliable and secure wireless communication and relatively lesser influence of the radiations on the user, the research trend has emphasized on the migration towards high-frequency THz spectrum [1, 2]. Recent research efforts have been focused to overcome the propagation and fabrication issues at THz and in developing THz sources, antennas, systems and applications [3]. In the past few years, the bandwidth of 0.1–10 THz has gained attention for the analysis and is highly anticipated in the applications of bio-sensing and imaging, fast and secure wireless systems, and radar communication [4, 5]. Numerous remarkable features of the THz band, for instance, high resolution of imaging, high confidentiality and data security, high penetrability of smoke or dust and wide available bandwidth, are promising for THz detectors, imaging and communication devices. Moreover, due to high absorption levels of THz waves by the water molecules and limited penetration ability into the human body, it has low tendency to produce hazardous ionization of biological tissues, and a favourable choice in the biomedical scanners.

A high-performance THz antenna is regarded as an essential unit, and several aspects need to be considered to develop an antenna design able to fulfil the demands of THz applications [6]. The progress has been made in the exploitation of novel materials instead of a copper-based radiating patch due to high

loss and degradation in efficiency as a result of a decrease in skin depth and conductivity at THz. Carbon-based materials i.e. graphene, and carbon nanotubes have found promising in this regard [7]. Perovskite compounds, due to the features such as superconductivity, ferroelectricity and low cost, have gained focus in various novel applications [8]. In this paper, the prospective perovskite antenna in THz bands is investigated.

II. PEROVSKITE ANTENNA DESIGN

The proposed antenna is designed and numerically analysed by using CST Microwave Studio (2018). The designed perovskite-based antenna is tested in simulation at the room temperature of 293 K. Perovskite material is constructed in the CST by using the measured complex permittivity values demonstrated in [9]. Fig. 1 shows the antenna design with the dimensions $40 \times 40 \times 10 \mu\text{m}^3$, consisting of a Perovskite based rectangular patch, while the ground plane and feedline are made of copper. Thin flexible film of polyamide is used as a substrate (dielectric constant, $\epsilon_r = 4.5$ and loss tangent, $\tan\delta = 0.0027$).

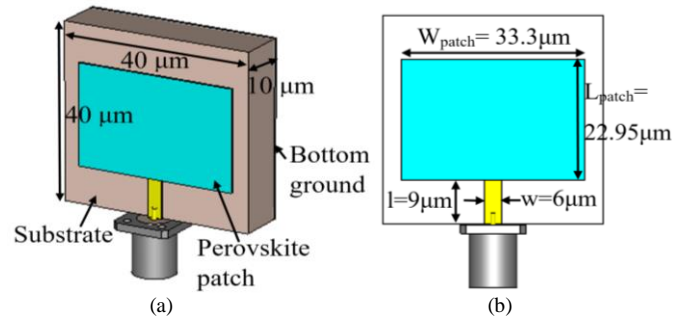


Fig. 1. Proposed perovskite-based THz antenna: (a) simulated antenna design; (b) Perovskite patch and copper feed line in the antenna prototype.

III. RESULT AND DISCUSSION

The reflection coefficient (S_{11}) plot of Fig. 2 demonstrates two significant bands while taking -10 dB as a reference. The band-I ranges from 3.6–7.4 THz and constitutes two dominant resonances at 5.18 THz and 6.98 THz respectively. The Band-II covers the range of 8.25–10.0 THz with an obvious resonant dip at 8.8 THz. The parametric analysis is carried out on the radiating length of the antenna and shown in Fig. 3. It has been

observed that with the increase in length from 20.95 μm to 29.7 μm , the resonant frequency can be tuned towards lower range.

The gain and efficiency versus frequency plots are shown in Fig. 4, which indicates that the realized gain varies from 4–8 dBi in the overall operating range. The gain magnitude is above 4 dBi in the almost complete bandwidth. Simulated results of Fig. 4 also present good efficiency of $\sim 88\%$ at 5.185 THz, which is comparable to the reported graphene-based THz antenna in [10].

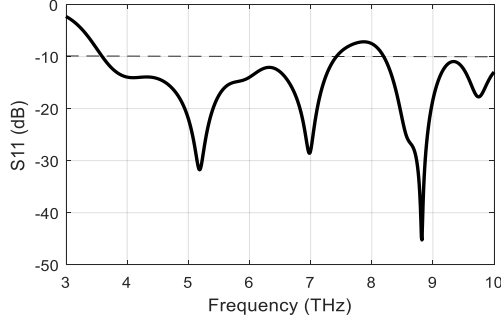


Fig. 2. Simulated S_{11} profile of the designed perovskite-based THz antenna.

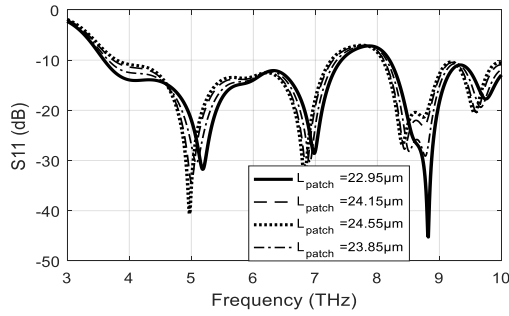


Fig. 3. Parametric analysis of the radiating length of the designed perovskite-based THz antenna.

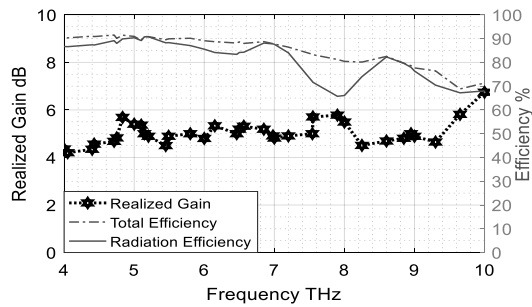


Fig. 4. Realized gain and efficiency plots of the proposed perovskite-based THz antenna.

The E and H-plane radiation patterns of the designed antenna at the three major resonant frequencies are illustrated in Fig. 5. The main lobe with 4.53 dBi is obtained at the resonance of 5.185 THz, while an increase in the magnitude of main lobe gain is observed at 6.985 THz and 8.821 THz resonances. Though the radiation is not perfect broadside in the complete operating range, yet this effect is obvious when the antenna is designed to

cover a wide bandwidth. The high bandwidth, reasonable gain magnitudes and high efficiency depict that the perovskite can be deployed as a radiating element in the THz patch antennas.

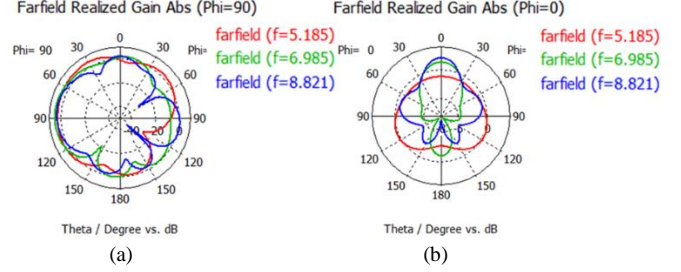


Fig. 5. Proposed perovskite-based THz antenna: (a) Bottom metallic ground of the simulated antenna; (b) Front view of the simulated antenna.

IV. CONCLUSION

The THz antennas are anticipated to ensure a high-resolution imaging for the biomedical applications due to their short wavelength and high directivity. Novel materials have been developed for the potential deployment in modern THz systems to achieve high performance. The results show that the designed antenna covers two THz bands, i.e. 3.6–7.4 THz and 8.25–10.0 THz. The realized gain of the antenna is above 4 dBi and radiation efficiency is above 70% in overall operating bandwidth. The antenna is regarded as a potential candidate for the future short-range THz communications.

ACKNOWLEDGEMENT

Sincere gratitude of the authors to the Libyan Government for this research support.

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